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Green Roof Analysis and Design Software Calculator in Egypt

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Abstract

Green Roofs Analysis and Design software (GRAD) 1st version is a data-base-driven tool, which has been developed from detailed green roofs sections calculation at residential buildings according to the Egyptian climate zones, and Egyptian energy code. The goal was to create an easy tool that enabled architects, developers, and others to ease the process of green roof sections use and selection. In addition to obtain quick estimates of how green roof design decisions might impact building energy use and design decisions. The Green Roofs Analysis and Design program performs the green roof sections within a database of 784 green roof sections, which has been designed at a previous stage, to estimate the residential roof building energy reduction in Egypt. The outputs from each user provide basic characteristics of a green roof project; produces information for two green roof systems (built-in system, module system). The program can be used in the design and analysis of green roofs sections in Egypt; and also the software program can be used to compare the impact of different variables which effect on buildings thermal behavior.

Keywords: Green roofs, Egyptian climate zones, Green roofs energy saving.

1. Introduction

Green roof has considered as an effective way to resolve many environmental problems [1]. Green roofs provide many benefits compared to traditional roofs [2], and such roofs work to mitigate the impact of heat islands in cities, improve rainwater management as well as reduce air pollution and noise. They also help reduce carbon emissions in cities [3], and can thereby overcome the dearth of parks and green spaces [4].

Another important benefit is the insulation provided by green roofs, which reduces heat transfer through the roof and the temperature on the roof surface. It means more energy savings prospect which motivates the present study [5].

In spite of the importance of using green roofs on buildings, the use of green roofs in Egypt is still absent; Egypt has been suffering recently from increasing energy demand compared to production rates, especially in the residential sector as a result of high population growth and high temperatures [6, and 7]. In this context green roofs help in solving the problem of lack of preference for selecting the last floor of the residential building due to the problems of thermal and moisture insulation, where it works as an extra layer on the roof that reduces thermal stress on the roof of the top floor.

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The study presents a tool to facilitate the design and the selection of the green roof sections, where the user enters design requirements and the program calculates and analyzes the appropriate section.

The main objective of this paper is to propose the Green Roofs Analysis and Design software program and introduce the definition of the determinants of the program.

The research provides information about the database of the green roof sections in the program, with an explanation of the inputs and outputs of the software, and how to take advantage of the program with examples of some of the important results extracted from the software.

2. GRAD software database (green roofs sections)

The data base of GRAD software is based on a range of green roof sections, which is designed at residential buildings according to the Egyptian climate zones as well as the Egyptian energy code.

These green roof sections are created according to two main phases: 1) Green roofs sections design at residential buildings in Egypt, 2) Evaluation of green roof sections according to Egyptian climate zones.

2.1. Green roof sections design

Many studies proved that the different variables assemblies affect the thermal performance of the green roof in different climate [8-11], so the green roof sections are designed according to specific variables that fits with the Egyptian environment, where many considerations were taken during the design process, such as the most important goals for green roofs setup in

Egypt, and green roofs systems, types of vegetation and growing medias green roofs systems in Egypt, as follows:

- Vegetation type.
- Growing media type.
- Growing media depth.
- Growing media moisture.
- The thickness of reinforced concrete slab, see Table(1).

Table 1: Green roof sections variables according to the study.

Variables	Variable 1	Variable 2	Variable3
Vegetation type	Grass	Sedum	shrubs
Thickness of growing media/ soil depth	100mm	150mm	250mm
Growing media type	Rice husk	pumice	clay
Growing media moisture	Rice husk (10- 22%)	Pumice 25% & sand 75% (11- 55%)	Clay (5- 25%)
Reinforced concrete slab thickness	120mm	200mm	------

Based on the previous green roof layers' variables, there are: three vegetation type (sedum, grass & shrubs) × three soil type (rice husk, pumice-sand & clay soil) × three depth of soil (100mm & 150mm & 250mm) × two soil moisture degree × two thickness of concrete slab (120mm & 200mm) = 96 valid green roof sections).

The next step for designing green roof sections is to calculate physical properties (density, specific heat, and sections weight …), and also to calculate the thermal properties (thermal conductivity, thermal resistance,….) for each designed green roof section were calculated in order to be applied on the different climate zones of Egypt.

There are two main installation systems for green roofs at general—built-in-place green roof system and green roof module system [12], all of these sections are designed and calculated to the main two green roof installation systems in Egypt.

- Built-in-place green roofs: this system is used in most conventional green roofs, which consists of series of components that must be installed in layers on a roof surface, see Table (2).
- Green roof module system: basically, modular design tries to subdivide a system into small standard parts that are easily interchangeable. For green roof systems, modular designs are often self-contained, pre-planted blocks giving an instant greening effect and greater design flexibility. Module system is essentially green roof plants grown in movable trays or crate [13, and14].

Table 2: Example of designed green roof sections

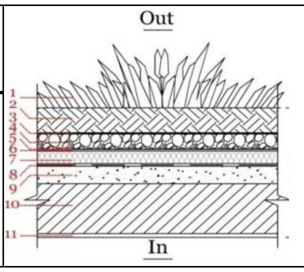
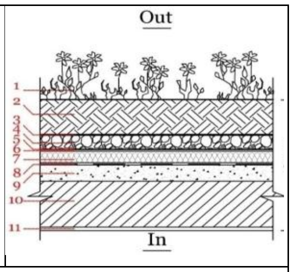
Description	Inverted roof section (200mm reinforced concrete) with grass as a vegetation layer & rice husk (10% moisture 100mm)	Inverted roof section (200mm reinforced concrete) with sedum as a vegetation layer & clay growing media (25% moisture 150mm
Sections shape		

Table 2 continued

Sections layers	1. Sedum (vegetation layer) 2. Rice husk growing media 3. Filter sheet 4. Drainage layer 5. Root barrier 6. Waterproof layer 7. Thermal insulation 8. vapor barrier 9. Ordinary Concrete 10.Reinforced Concrete 11. Internal Plaster	1. Grass (vegetation layer) 2. Clay media 3. Filter sheet 4. Drainage layer 5. Root barrier 6. Waterproof layer 7. Thermal insulation 8. vapor barrier 9. Ordinary Concrete 10.Reinforced Concrete 11. Internal Plaster

2.2. Green roofs sections evaluation

In the Egyptian Code, Egypt was divided into eight climate zones [15], each of the climate zones was clarified and cities located in it were defined, see Table(3).

Table 3: Eight climate zones of Egypt [16].

	Climate zone	Egyptian cities
1	**North Coast**	El Arish-Port Said- Damietta-Elbehera-Alexandria- Marsa Matrouh-Salloum
2	**Delta & Cairo**	Cairo- Garabiyh - Dakahlia - Sharkiha
3	**North Upper Egypt**	BeniSuef - Fayoum - Minya
4	**South Upper Egypt**	Assiut - Sohag - Qena to Edfu
5	**Eastern Coast.**	Hurghada - Suez - MarsaAlam – Ras Sidr - Sharm el Sheikh - Taba - Dahab
6	**Heights.**	St. Catherine - Tur
7	**Desert.**	Bahariya Oasis - Siwa - Farafra -aldakhlh - Owaynat
8	**South Egypt.**	Aswan - Toshka - Abu Simbel

Green roofs have been divided sections through applied to the eight climate zones of Egypt.

The application of green roofs sections has been designed on various climatic regions of Egypt according to Egyptian energy code, in order to improve energy efficiency in buildings, through the evaluation of these sections in terms of:

- Green roof sections function evaluation.
- Green roof sections thermal energy evaluation.
- Green roof sections electricity energy evaluation.
- Green roof sections environment evaluation.

In the Egyptian code, the allowed R-Value allowed for roofs at un-conditioned and conditioned buildings is stated for each climate zone. R-Value for section before and after insulation ≥ R-value Allowed. This is what has been applied on green roof sections in function evaluation [12].

Green roof sections thermal energy evaluation is done according to the calculation of rate of heat transfer in summer (Q summer), winter (Q winter), and average in all year (Q), for each designed green roof section [16, and 17].

Green roof sections electricity energy evaluation is done according to the calculation of rate of electricity consumption in summer reduction (E summer) & winter (E winter), and average in all year (E Year), for each designed green roof section [16-19].

Finally, green roof sections environment evaluation is done according to the calculation of CO_2 production at case of coal plant and CO_2 production at case of mixed solar/fossil [19, and 20].

By the end of this part there are 96 green roof sections × 8 Egyptian (region-city) = 768 green roof sections.

With the following characterization:

- Rate of Heat Transfer in summer Watt/m^2.
- Rate of Heat Transfer in winter Watt/m^2.
- Average of Rate of Heat Transfer reduction % Watt/m^2.
- Rate of Electricity Consumption in summer kwh/m^2/day.
- Rate of Electricity Consumption in winter kwh/m^2/day.
- Electricity Consumption reduction %.
- CO_2 reduction at Case of Coal Plant kg/m^2/day.
- CO_2 reduction at Case of Mixed Solar/Fossil kg/m^2/day.
- Weight /m^2 (kg/m^2) with green roof layers.

The following flowchart concludes the previously discussed design methodology procedures, see Figure(1).

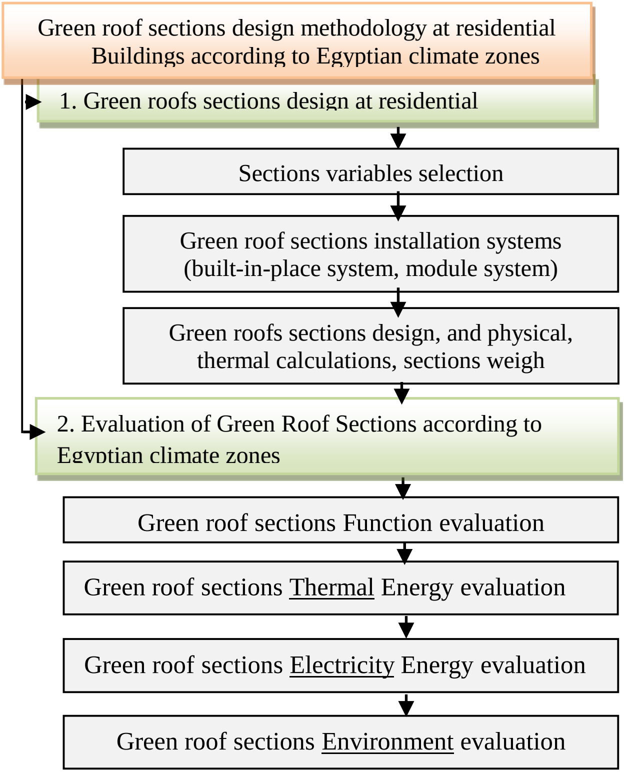


Figure1: Green roof sections design methodology.

3. Green roofs analysis and design software program (GRAD)

As mentioned before the green roof analysis & design software includes green roof sections within a database of 784 sections to estimate the whole building energy use, based on certain variables in the layers of green roof sections. Therefore, the goal was to create a tool to facilitate the selection and design of the sections, to obtain quick estimates of how green roof design decisions might impact building energy use. The result of this effort- green roofs analysis and design software program (GRAD) has been proposed and is currently in its 1st version.

3.1. The inputs of GRAD software

In GRAD software, inputs are dividing into data for building information and data of both green roof section characteristics and energy saving requirements.

The building information

The input screen of this section requests the following information:

- Building location (choice from the eight climate zones).
- City of the building (choice from Egypt cities).
- Total building roof area /m^2
- Depth of concrete slab (choice from 120mm thickness, or 200mm thickness).

Green roof information

- Growing media depth (choice from 100mm depth, 150mm depth, or 250mm depth).
- If green roof irrigated (Yes –No).

- Vegetation type (sedum –grass- shrub).
- Green roof cover area percentage %.

Green roof energy saving requirements

After entering the data of the building information, then the user chooses from two sets: design by electrical energy saving (electricity consumption reduction), or design by environment (average of co_2 reduction) of fossil.

Average of the section weight

The user enters the average of the section weight required (choice from 0- 700, 700- 900, and more than 900 kg/m^2).

The installation system

The user selects the green roof required installation system, and the choice is between built-in-place green roofs system, which is often used in new buildings, or green roof module system, which is often used in existing buildings.

The following table a summary of the green roof analysis and design software program input data, see table (4).

Table 4: Summary of GRAD software input data.

	Variable	Values
Building information	Building Location	The eight climate zones of Egypt.
	City of the building	(Choice from Egypt cities).
	Total building roof area	---m^2
	Depth of concrete slab	120, 200mm
Green roof information	Growing media depth	100, 150, 200mm
	If green roof irrigated	Yes, No
	Vegetation type	Sedum, Grass, Shrub
	Green roof cover area	-----%
	Section weight	(0- 700, 700-900, and more than 900 kg/m^2)
	Green roof installation system	Built-in-place, Module system
	Rate of electricity consumption reduction	(0-30%, 30-50 %, 50-100%) kwh/m^2/day
	Average of co_2 reduction	0-2, more than 2 kg/m2/day

3.2. GRAD software modules

Green roofs analysis and design software program consists of two basic modules; the first one named green roofs analysis, and the sound named green roofs design.

The first module supposes that the user of the software have a background about the green roof section required, and required the analysis of that green roof section from the software program.

The second module supposes that the user of the software knows the average of energy saving required, and required the design of that green roof section from the software program.

Green roofs analysis module

In green roofs analysis module, the user enters the green roof sections' layers characteristics according to his requirements, and then the software analyzes and characterizes the green roof given sections, see Figure(2).

Figure 2: The input screen of the first module green roofs analysis.

Steps to use green roof analysis module

Step 1: From the starter screen choose green roof analysis.

Step 2: From the building information group:

1- Choose building location (choice from eight climate zones in Egypt).
2- Choose city of the building (choice from Egypt cities).
3- Enter total building roof area /m^2
4- Enter depth of concrete slab.(120mm -200mm)

Step 3: From the green roof information group:

5- Choose growing media depth (100mm- 150mm- 250mm).
6- Choose if green roof irrigated (Yes –No).
7- Choose vegetation type (sedum –grass- shrub).
8- Enter Green roof cover area percentage.
9- Choose results.

10-Green roofs design module

In the sound module, Green Roofs design, the user enters the average of energy saving and the efficiency required, and then the software makes selection and characterization of the appropriate green roof section, see Figure (2). In addition, the flowchart which describes the algorithmic process of the proposed software and explain how it works are presented and summarized in Figure (3).

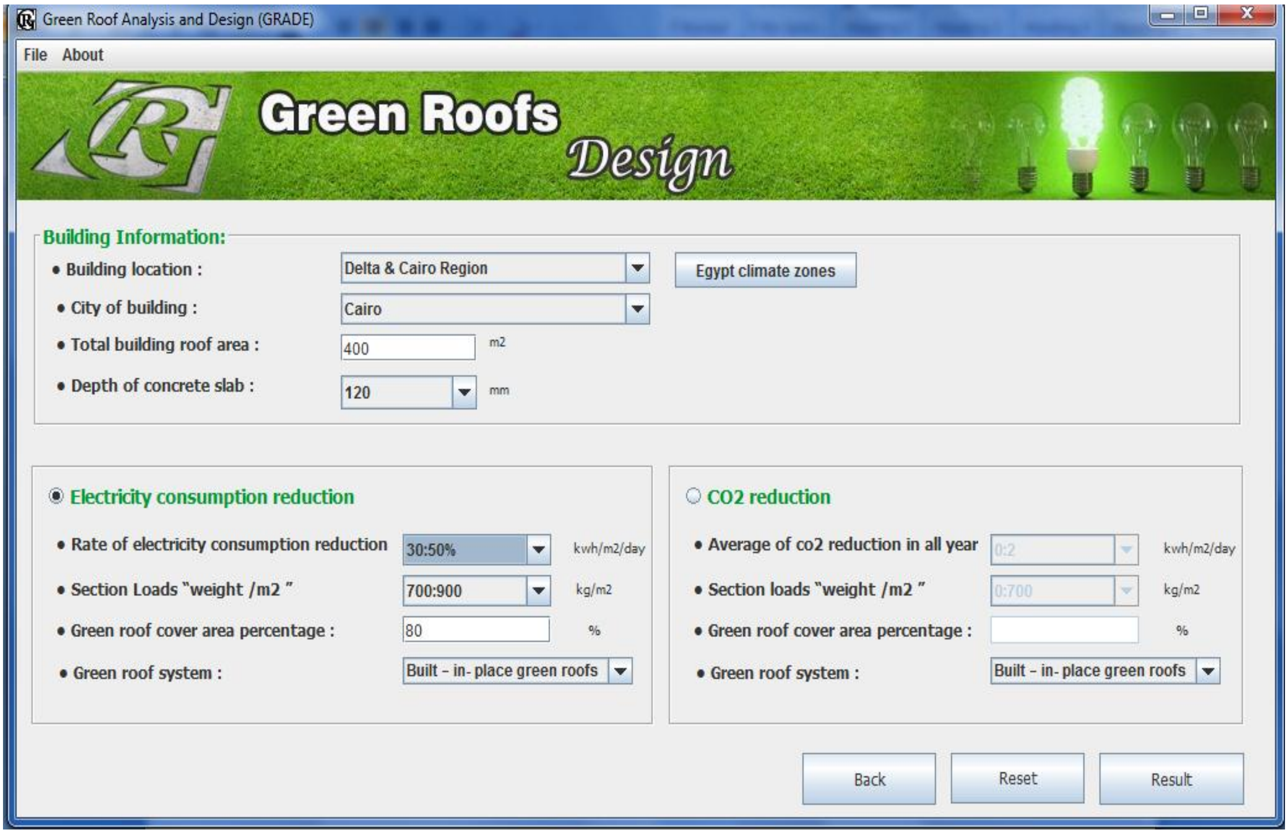


Figure 3: The input screen of the sound module green roofs design.

Steps to use green roof design module

Step 1: From the starter screen choose green roof design.

Step 2: From the building information group:

1- Choose building location (choice from eight climate zones in Egypt).
2- Choose city of the building (choice from Egypt cities).
3- Enter total building roof area /m^2
4- Enter depth of concrete slab.(120mm -200mm)

Choose from two groups "Design by electrical energy saving (electricity consumption reduction)" or "Design by environment (average of co_2 reduction)."

Step 3: From (Design by electrical energy saving (electricity consumption reduction) group.

5- Rate of electricity consumption reduction kwh/m^2/day (0- 30%, 30- 50%, and 50- 100%).

6- Select section "weight/m^2" (0- 700, 700- 900, and more than 900 kg/m^2).
7- Enter green roof cover area percentage %.
8- Choose results.

The following figure is the flow chart of the green roofs analysis and design software, see figure (4).

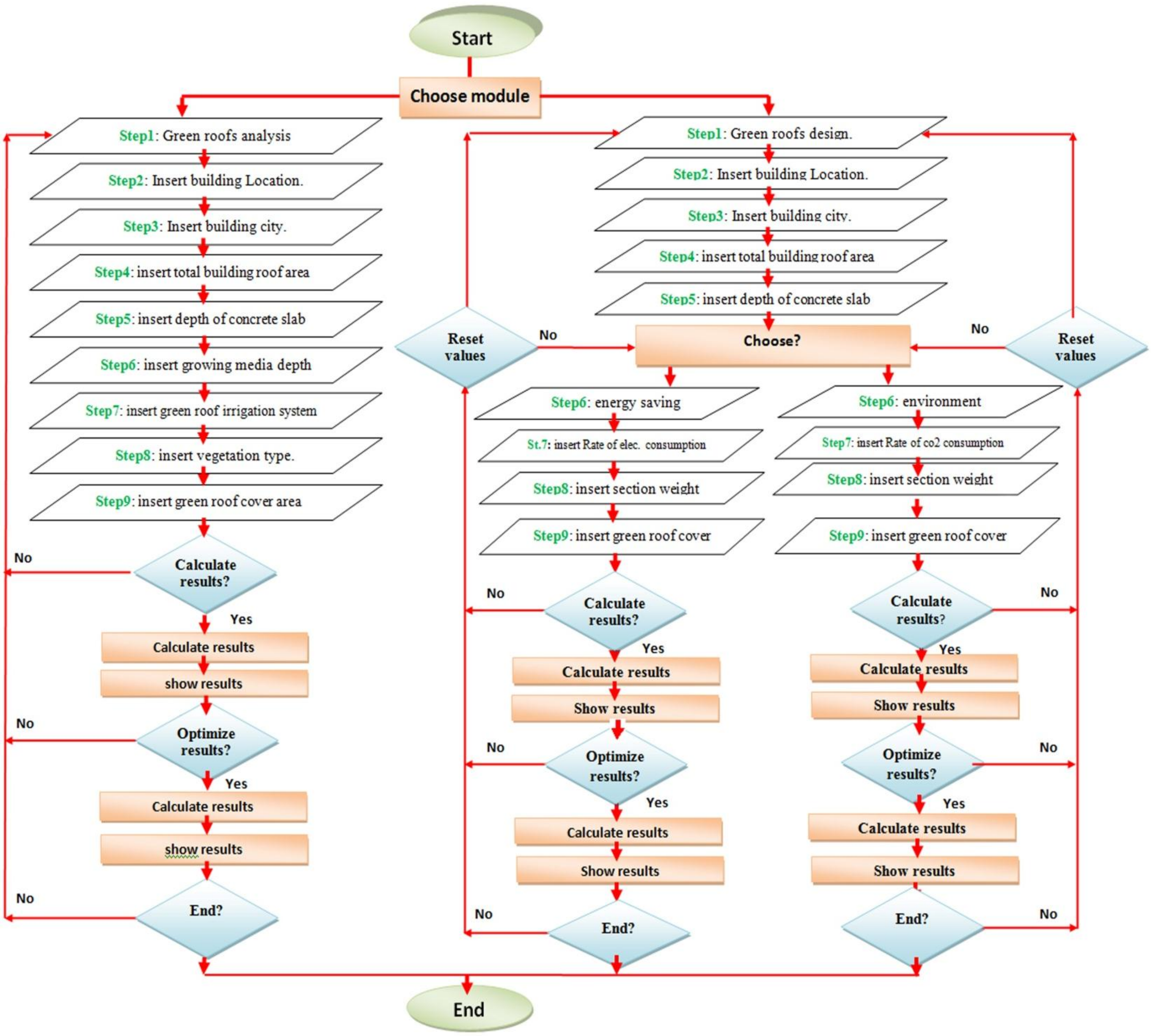


Figure 4: Flow chart of green roofs analysis & design software

3.3. The outputs of GRAD software

After entering and finishing the input process for the required data, GRAD software calculates and analyzes the result of the selected sections.

The output results of green roof sections are listed according to the input data entered see Figure (5). It includes green roof sections description and green roof sections characterization, then green roof sections optimization, as follows:

Sections description

This part includes the name of sections (section shape – vegetation type – growing media type - thickness of growing media– the moisture of the growing media).

Sections characterization

This part includes:

- Rate of Heat Transfer in summer Watt/m^2.
- Rate of Heat Transfer in winter Watt/m^2.
- Average of Rate of Heat Transfer reduction % Watt/m^2.
- Rate of Electricity Consumption in summer kwh/m^2/day.
- Rate of Electricity Consumption in winter kwh/m^2/day.
- Electricity Consumption reduction %.
- CO_2 reduction
- Weight /m^2 (kg/m^2) with green roof layers.

Sections optimization

As it mentioned before in the outputs part, the result of GRAD software is a number of characterized and analyzed green roof sections.
The number of these calculated sections depends on the inputs which have been entered in the software, where in some cases the results show more than one calculated sections, so the user maybe gets confused about choosing the most appropriate section. So in GRAD software green roof sections could be optimized in order to select the most appropriate green roof section. The optimizing step is to reorganize the sections according to the best overall performance (less weight - higher rate of heat transfer reduction - higher rate of electricity consumption reduction).

4. GRAD software validation

In order to validate the proposed, some green roofs sections resulting from the study and the software program were simulated with another valid software program. The valid software program is (Green roof energy saving design and analysis GREC – Version 02), and both results were compared.

4.1. Overview of the validation program

This software program was developed through a collaboration involving researchers and staff at Portland State University, University of Toronto, and Green Roofs for Healthy Cities. The effort was funded by the US Green Building Council with additional financial and in-kind support from University of Toronto, Portland State University, GRHC, and Environment Canada.

The Green Roof Energy Calculator (GREC)—has been available on-line since 2011 and is currently in its 2nd version. The (GREC) software is created to develop a proposal to create a much simplified on-line tool for use by non-energy modeling experts [21].

The validation program of Green Roof Energy Calculator (GREC) has only database of Canada & America states climate zones, so to be able to compare the results of the energy simulation data from the two software program, first we must find a matching climate zone between Egypt and US to do the validation. This matching of the climate zones was obtained according to Köppen climate classification.

Köppen climate classification

The Köppen Climate classification system is the most widely used system for classifying the world's climates. Its categories are based on the annual and monthly averages of temperature and precipitation, vegetation-based empirical climate classification system developed by German botanist-climatologist Wladimir Köppen. His aim was to devise formulas that would define climatic boundaries in such a way as to correspond to those of the vegetation zones that were being mapped for the first time during his life time [22].

According to Köppen climate classification the nearest weather conditions to Egypt (Alexandria, Egypt) weather is Phoenix, Arizona, United States.

So the validation process of green roof sections which is located in Alexandria city, north coast climate zone, will be compared to Phoenix city, Arizona, United States.

4.3. The validation process

The following table (5) shows the input data in both software programs for the same selected green roof sections and results were compared.

Table 5: The comparison input data of Green roofs sections analysis & design program “GRAD” and The Green Roof Energy Calculator "GREC" [23, and 24].

	Green roofs sections analysis & design program “GRAD”	**Green Roof Energy Calculator "GREC"**
Location	North coast zone (Alexandria, Egypt)	Phoenix, Arizona
Vegetation type	Sedum	LAI =1
	Grasses	LAI =2.5
	shrubs	LAI = 4
Growing media depth	100mm	4”
	150mm	6”
	250mm	10”
Note : This Comparison included that there is no irrigation system of plants, roof area is 100m^2 and for the properties of the growing media were taken from the average value of the different characteristics of the growing media the percentage of green roof cover area is 100%.		

Where:
Leaf area index (LAI): leaf surface area relative to the corresponding surface area of ground [25] .

The following table (6) shows the comparison result between Green roof sections analysis & design software program rate of heat transfer and Green roof energy saving rate of heat transfer.

Table 6: Rate of heat transfer calculation from the (green roof sections analysis & design software program “GRAD”) and the green roof energy saving calculator software program “GREC”)

	Growing media depth / **Vegetation type**	**100mm**	**150mm**	**250mm**
GRAD software	Sedum	1	1.5	1.8
	Grass	0.8	0.9	1.2
	Shrub	---	1.06	1.3
GREC software	Sedum	0.8	1.13	1.3
	Grass	1.07	1.2	1.4
	Shrub	---	1.33	1.66

The percentage of difference is calculated between the two output data sets and a difference of ± 10% is kept as the benchmark for accuracy.

In the comparison it is noticed that the results obtained through the simulations in the two software programs has percentage differences less than 10%. It was also noticed that there is good agreement between the results of the study and the results of the program, see Figure(5).

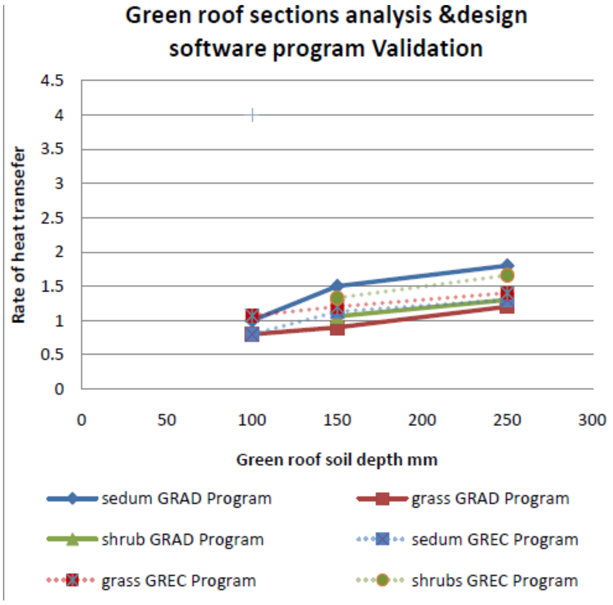


Figure 5: The Comparison between Green roof sections analysis & design software program rate of heat transfer and Green roof energy saving rate of heat transfer.

5. Discussion and observations

From GRAD software analysis and calculations of design green roof sections, it shows some interesting results.

The analysis shows that the green roof designed sections have a positive thermal impact on the building and have the potential to reduce the energy.

- Compared the different types of soil with different degrees of moisture of growing medias, a less dense of growing media has more air pockets and is hence a better insulator, where it was noticed that the higher the degree of soil moisture, the lower of insulation efficiency for the green roof sections, see Figure (6).

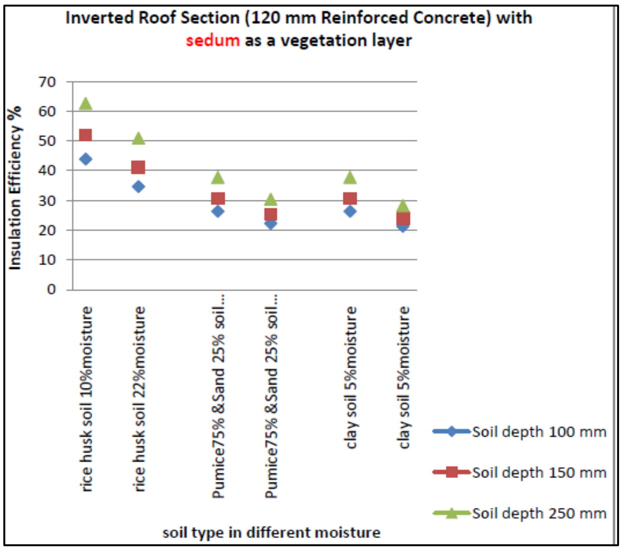


Figure 6: Study the effect of the degree of soil moisture on the insulation efficiency in the green roof sections in the case of (120mm Reinforced Concrete) with sedum as a vegetation layer.

- When an assessment done to compare the impact of the three different types of growing media the results from GRAD software show that the use of rice husk gave the highest results in terms of the efficiency of insulation, see Figure 7, in addition, studies have been undergoing to study the possibility of using rice husk instead of burning it and polluting the environment [26- 28], making it the first candidate to choose the best as a good soil for planting on green roofs in Egypt.

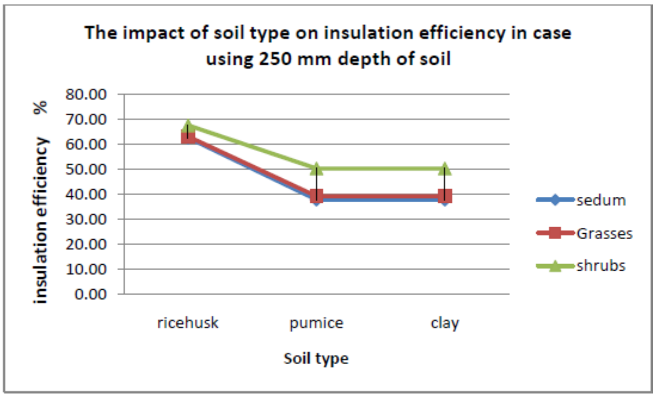


Figure 7: Study the effect of the soil type on the insulation efficiency in the green roof sections in the case of (120mm Reinforced Concrete) with 250 depth soil.

Finally, best results are obtained when using green roof sections in the south regions where it achieved maximum energy saving and efficiency insulation compared with the north regions.

6. Concluding remarks

The Green Roof Analysis and Design (GRAD) software has been developed based on 768 green roof sections.

The calculations of for GRAC software explore the roles of five green roof variables (vegetation type, growing media type, growing media thickness, growing media moisture content and thickness of concrete slab) according to eight climate zones of Egypt.

Outputs from GRAD characterize green roof sections and demonstrate possible energy saving from the selected sections.

The goal of the GRAD is to provide a broad user market (e.g. planners, architects, developers, building owners) with an easy tool to estimate of the effect of green roof design variables in design decisions.

7. Study Recommendations

- Due the importance green roofs in Egypt as proved in the study, the study recommends the need to apply green roof sections on the roofs of residential buildings in Egypt., and recommends starting activating the experience of the application of cultivation roofs of residential buildings in Egypt in the southern regions in Egypt, where it gave the best results in terms of achieving the highest efficiency of insulation and the highest save energy in the desert region and in the southern region of Egypt.
- Activating the role of the media to spread awareness to disseminate the experience of the application of cultivation the roofs of residential buildings in Egypt.

8. References

1. S. Celik, "The thermal insulation performance of green roof systems", Southern Illinois University Edwardsville, IGEC-6, 2011, p232.
2. H. Castleton, V. Stovin, S. Beck, and J. Davison, "Green roofs; building energy savings and the potential for retrofit," Energy and Buildings, vol. 42, pp. 1582-1591, 2010.
3. S. Carpenter, "Growing Green Guide", Victoria's guide to green roofs, walls & facades, National Library of Australia Cataloguing-in-Publication data, 2014, p7.
4. O. Buhairi, Diversion Project rooftops into gardens fruitful. Arab Republic of Egypt: Hans Seidel Foundation, 2009.
5. Growing Green Guide project partners (City of Melbourne, City of Stonington, City of Yarra, and City of Port Phillip, The University of Melbourne and the State of Victoria), 2013, P8.
6. M. Fahmy, M. M. Mahdy, and M. Nikolopoulou, "Prediction of future energy consumption reduction using GRC envelope optimization for residential buildings in Egypt," Energy and Buildings, vol. 70, 2014, pp. 186-193.
7. Annual activity report for (Egyptian electric utility and consumer protection regulatory agency), the annual report for the year 2012- 2013.
8. D.J.Sailor, ""Energy Performance of Green Roofs-The role of the roof in affecting building energy and the urban atmospheric environment," EPA Heat Island Reduction, 2010.
9. B. Kamel, S. Wahba, K. Nassar, And A. A. Salam, "Effectiveness of Green-Roof on Reducing Energy Consumption through Simulation Program for a Residential Building: Cairo, Egypt," Bridges, vol. 10, 2012, p. 97-175.
10. S. Mukherjee, P. La Roche, H. Architects, K. Konis, and J. H. Choi, "a parametric study of the thermal performance of green roofs through energy modeling," Master of Architecture, university of southern california, 2013.
11. D. J. Mischo, "Modular green roof system, apparatus and methods, including pre-seeded modular panels," Ed: Google Patents, 2005.
12. Chen and Williams, "Green roofs as an adaptation to climate change: modelling the green roof at the Burnley campus", The University of Melbourne, Research Report for CSIRO Climate Adaptation Flagship, 2009.
13. H, Doshi, et al., Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto, Ryerson University, Ontario, Canada, 2005.
14. N. Dunnett, N. Kingsbury, Planting Green Roofs and Living Walls, Timber Press, Oregon, 2004.
15. Utilities and Urban Development the Ministry of Housing, Egyptian Thermal Insulation Code, 2006.
16. National Center for Residential and Building Researches, Egyptian Thermal Insulation Code, Egypt, 2008.appendix D, p109.
17. R. Serway and J. Jewett, Physics for scientists and engineers with modern physics: Cengage learning, 2013, 6 th edition, p626.
18. M. Nassief. Evaluation of Electricity Consumption of a Residential Flat in Egypt American Journal of Electrical Power and Energy Systems. Vol. 3, No. 2, 2014, pp. 37-44. doi: 10.11648/j.epes.20140302.14
19. N. Abu-Samra, "Impact of Nano Technology on Building Envelope." PhD thesis Port Said University, 2013.p256
20. G. El-Rayies, Economic Maximizing the Exploitation of Daylight by Using the Green System to Achieve the Savings of Cost Energy, PhD thesis, Department of Architecture, Faculty of Engineering, University of Suez Canal, Port Said, 2010.
21. D. Sailor, B. Bass, "Development and features of the Green Roof Energy Calculator", Journal of Living Architecture, 2014.
22. C. Murray, C. Peel, L. Brian Finlayson, and A. Thomas McMahon, Hydrology and Earth System Sciences Discussions, 4 (2007), 439-73.
23. H. Tang, S. Ganguly, G. Zhang, M. Hofton, R. Nelson, and R Dubayah. "Characterizing Leaf Area Index (Lai) and Vertical Foliage Profile (Vfp) over the United States." (2015).
24. B. Bergamaschi, A. Homero, A. Genei, I. João, A. Cleusa B. Menegassi, K. Bianchi, M. Bruna, H. Machado, and C. Flavia. "Intercepted Solar Radiation by Maize Crops Subjected to Different Tillage Systems and Water Availability Levels." Pesquisa Agropecuária Brasileira 45, no. 12, 2010, P 1331-41.
25. O. Starry, "The Comparative Effects of Three Sedum Species on Green Roof Stormwater Retention", 2013.
26. A. A. Ramezanianpour, "Rice Husk Ash," in Cement Replacement Materials, ed: Springer, 2014, pp. 257-298.
27. Y. Matsumura, T. Minowa, and H. Yamamoto, "Amount, availability, and potential use of rice husk (agricultural residue) biomass as an energy resource in Japan," *Biomass and Bioenergy*, vol. 29, pp. 347-354, 2005.
28. H. Gao, Y. Liu, G. Zeng, W. Xu, T. Li, and W. Xia, "Characterization of Cr (VI) removal from aqueous solutions by a surplus agricultural waste—rice husk," *Journal of Hazardous Materials*, vol. 150, pp. 446-452, 2008. 4 Abdel –Sattar, Mohamed Anwar and Hanan El-Marzooki.